

Stability Analogy between a Mechanical Vibrator and Fluid Phases

A. Laesecke

*National Institute of Standards and Technology
Physical and Chemical Properties Division
Experimental Properties of Fluids Group
325 Broadway
Boulder, CO 80303 U.S.A*

L. Aumann

*Körting AG
Division S - Department STE
Badenstedter Strasse 56
30453 Hannover, Germany*

The frequency response of a sinusoidally driven vibrating wire was measured in vacuum over a wide range of amplitudes and at temperatures from 253 to 323 K. The measured resonances develop hystereses with increased forcing due to nonlinear wire motions. They can be interpreted in terms of the nonlinear differential equation of a generalized Duffing-Van der Pol oscillator whose stiffness and damping depend quadratically on the displacement.

The damped, forced behavior of the nonlinear oscillator shows a strong similarity to the phase behavior of a pure fluid. The topology of the stability map of the oscillator corresponds to the pressure-volume-temperature surface in the region of a first-order phase transition. This will be demonstrated using a perturbed-chain SAFT equation of state for chain-like molecules as a model for both the influence of driving force (temperature) and internal structure of the oscillator (chain length). The analogy between forcing and temperature suggests an inverse relationship which is supported by statistical mechanics. An interesting difference is that the single oscillator cannot attain two coexisting phases at the same time. Therefore, it is possible with such a system to access metastable states up to the stability limit. In fluid measurements with a number of oscillators on the order of Avogadro's constant, approach of the stability limit of a metastable phase is usually limited by fluctuation-induced, premature conversion to the conjugated absolute phase. The analogy with the single oscillator suggests that the metastable domain can be penetrated deeper when such experiments are carried out in microfluidic environments.